DA studies with Xsuite

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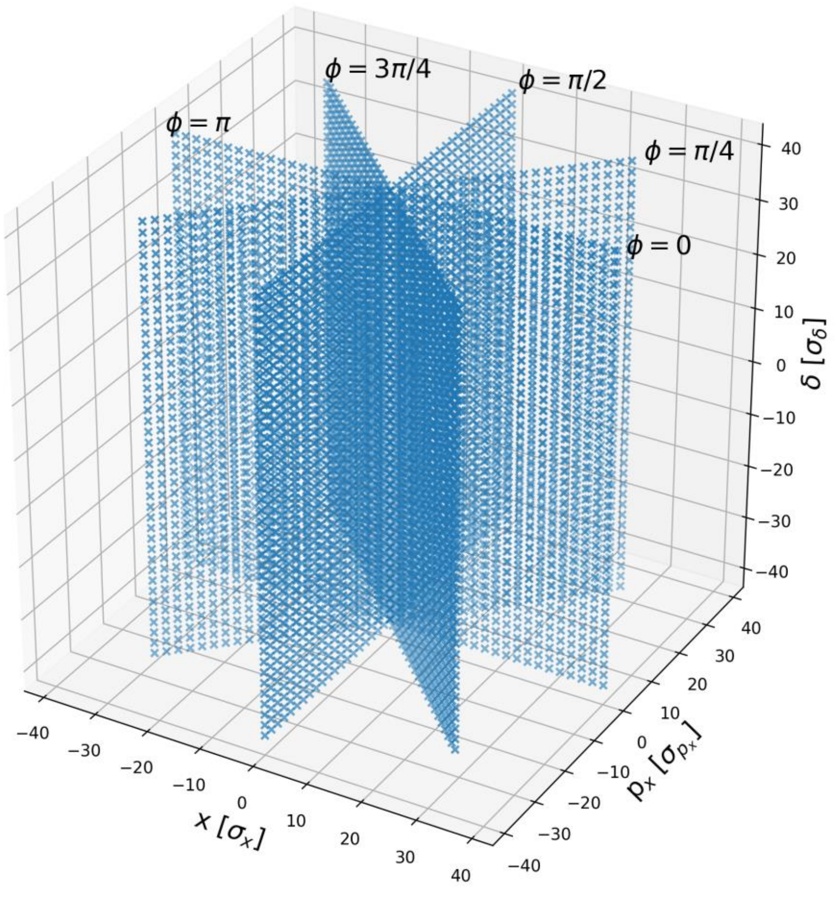
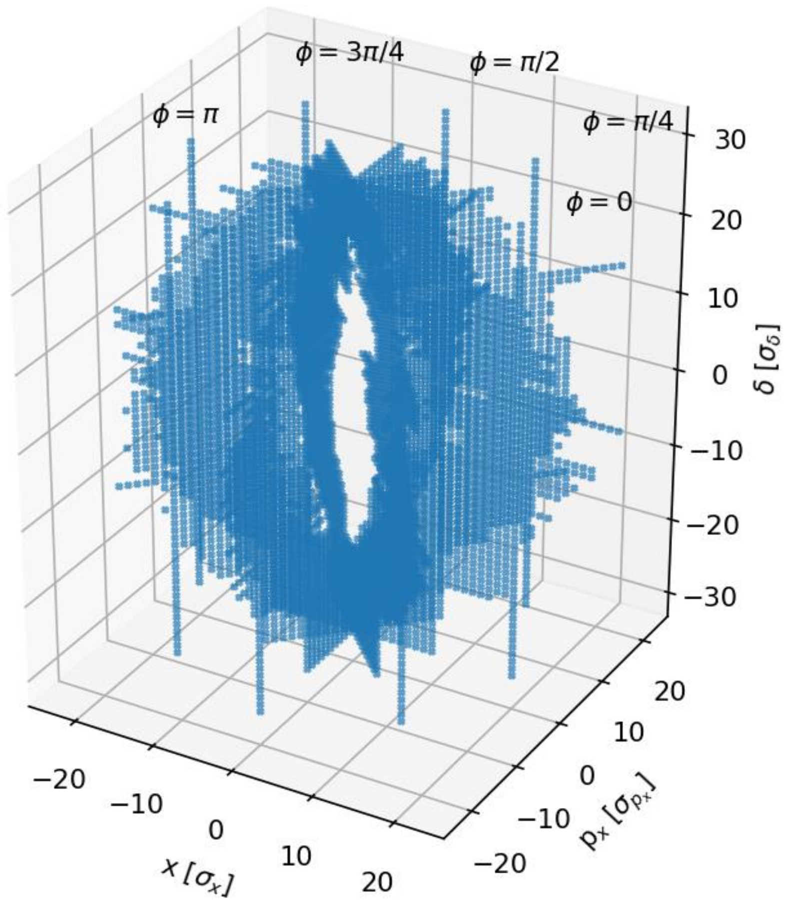
189th FCC-ee Accelerator Design Meeting – July 25th, 2024

Thanks to K. Oide

Oide's DA - Macroparticle grid



'Brute force' grid

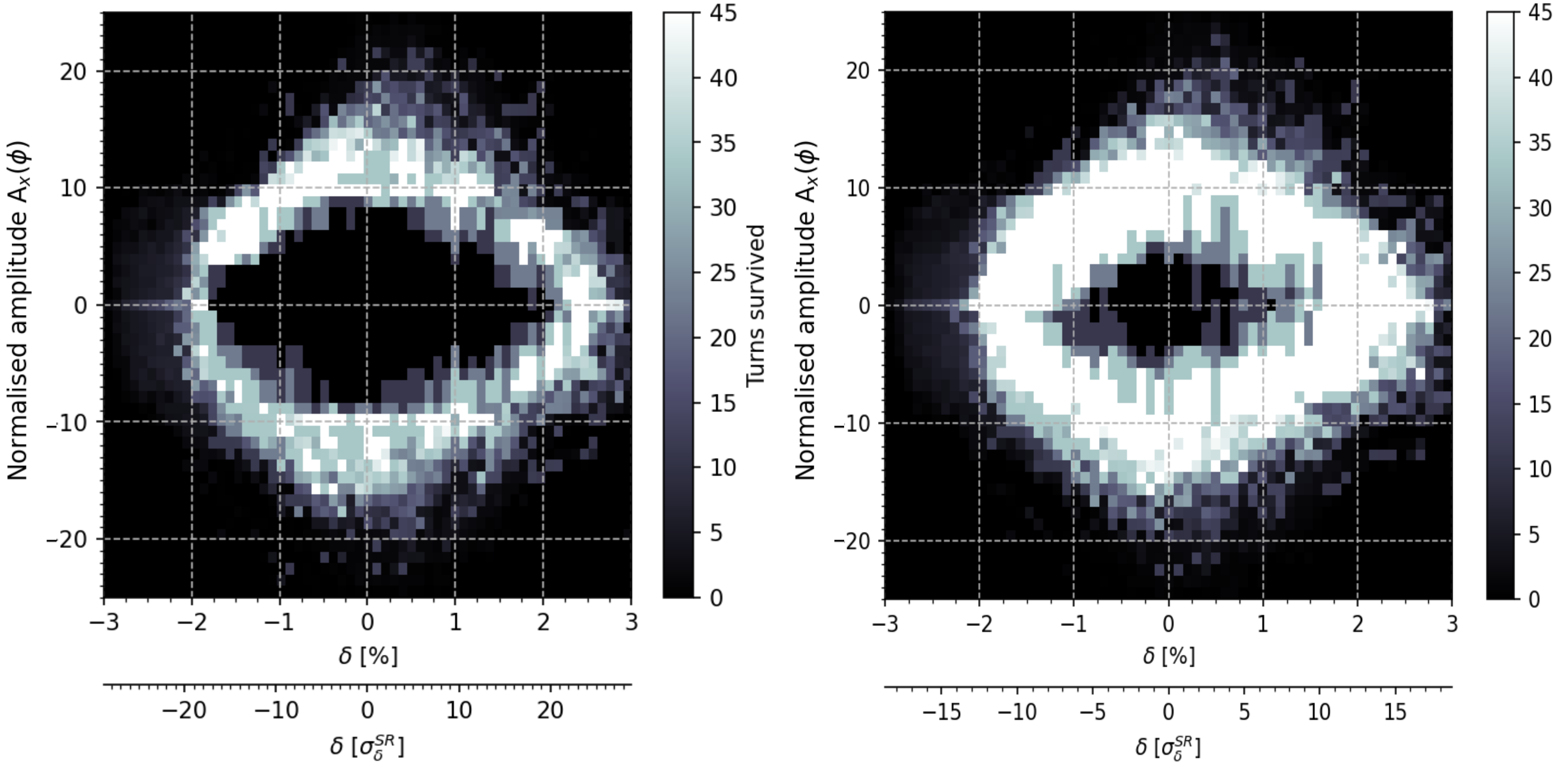


Grid resulting from bisection

Resulting DA

As you increase the ‘depth’ of tracked macroparticle in action J, the central area becomes increasingly whiter, proving the particles survived.

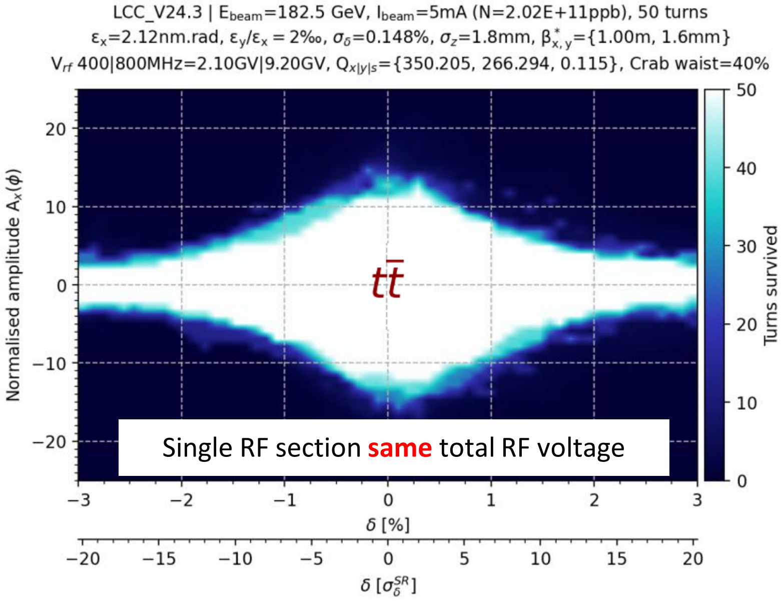
Some parts of the central region appear less white because of the average between phase planes because some planes have no data at this (δ,J) position.

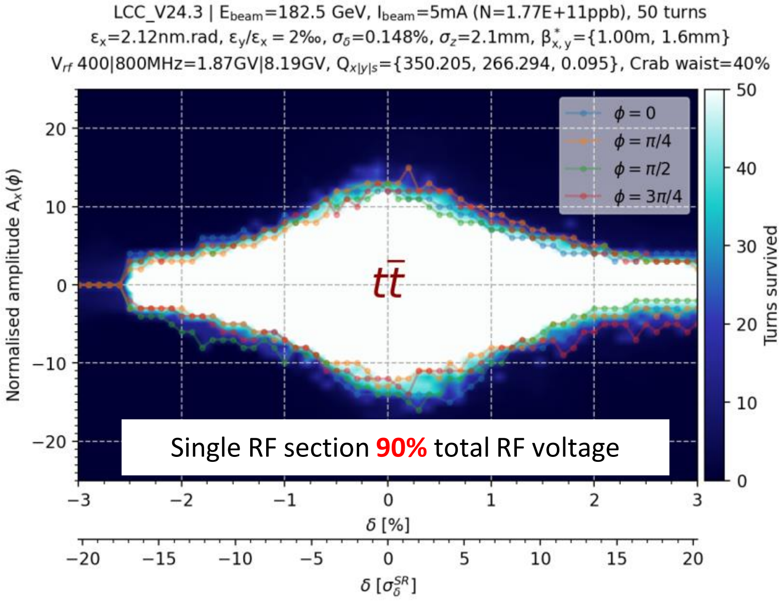


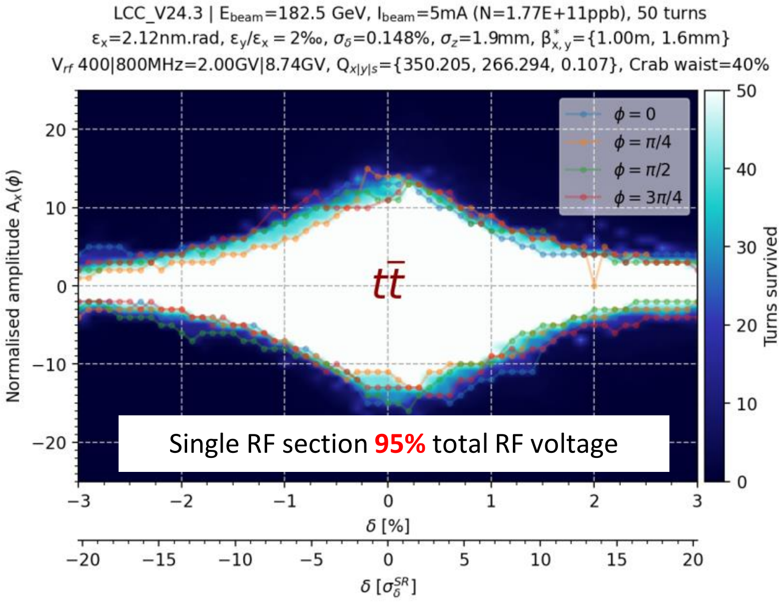
Reduction to one RF section

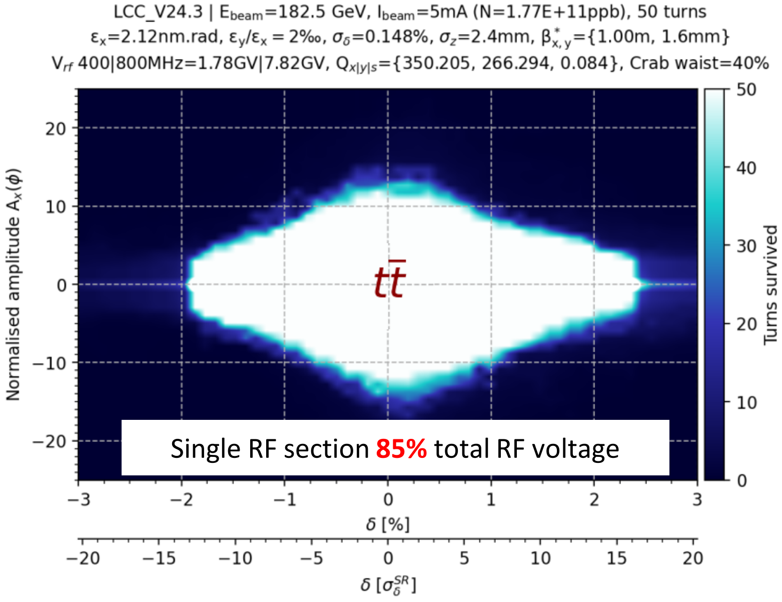
From 4 RF cavities at 400MHz evenly distributed in the ring (one in each straight section) to **1 RF section** including 400 MHz RF cavities and 800 MHz RF cavities.

Single RF section for the LCC lattice (nominal)









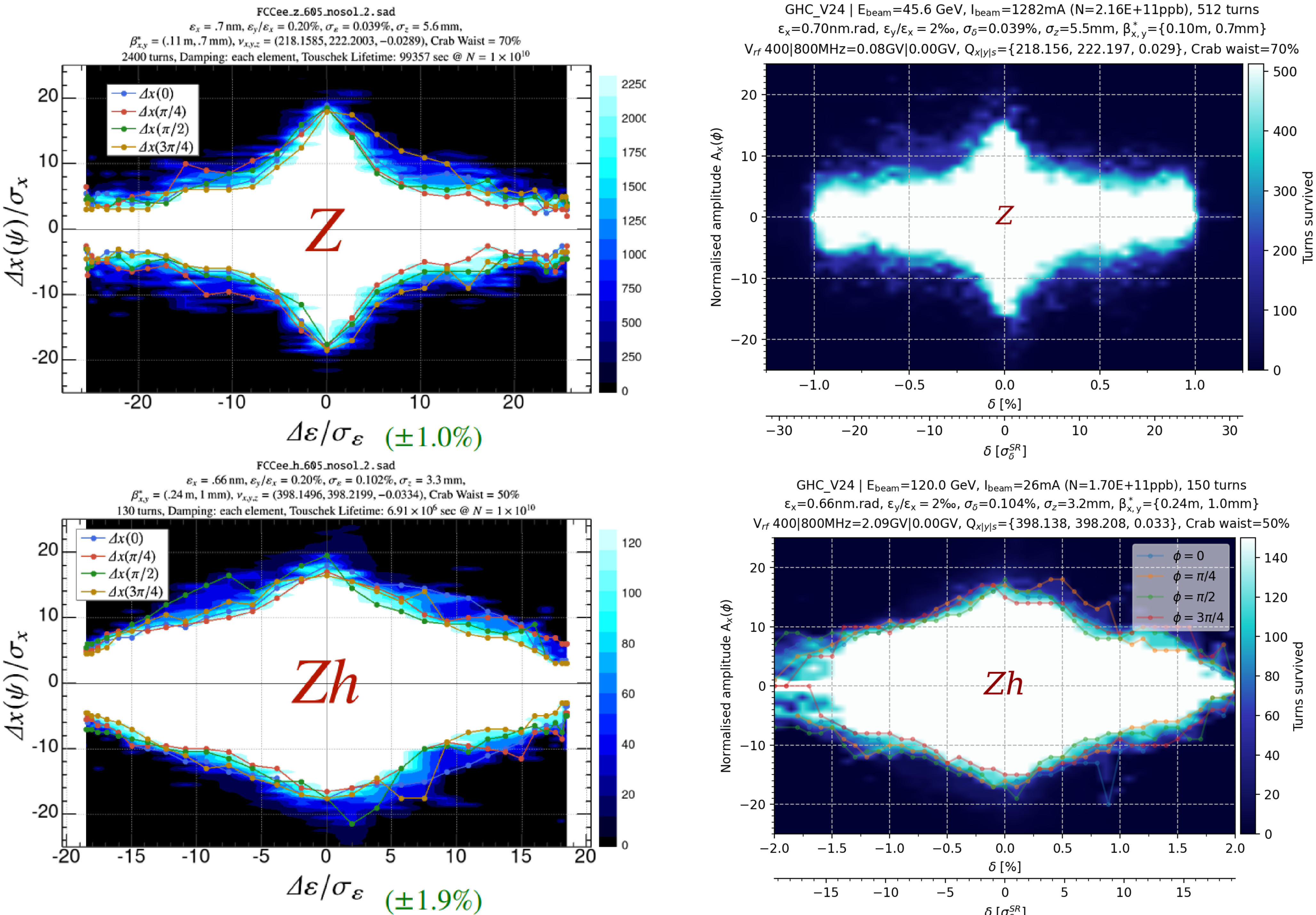
Attempt to get the same synchrotron tune as GHC lattice (Q_s=0.089).

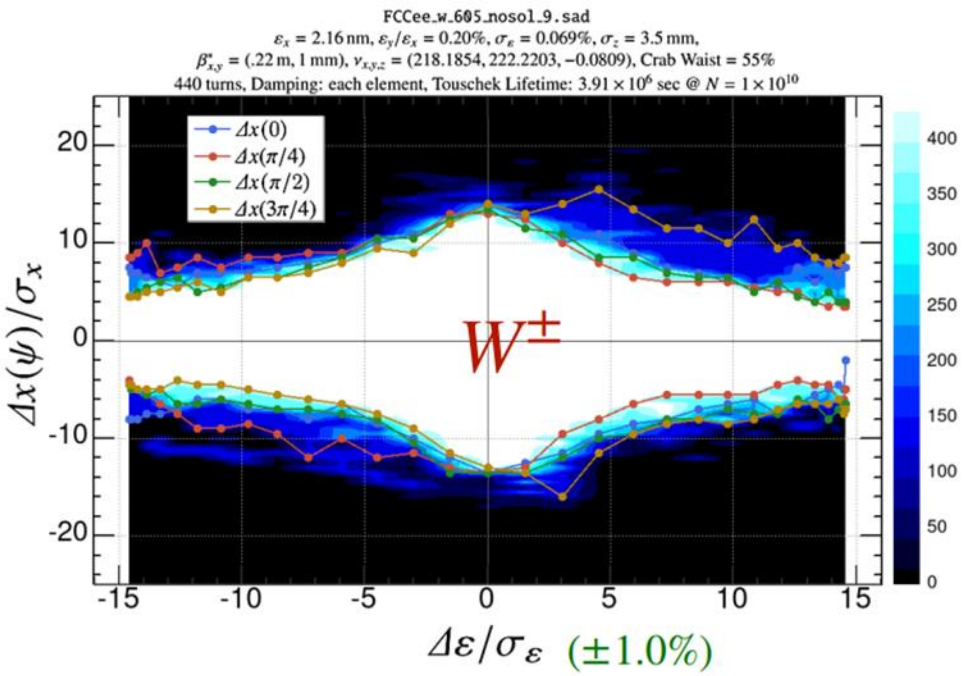
The energy loss per turn is smaller for LCC by 10-12%,

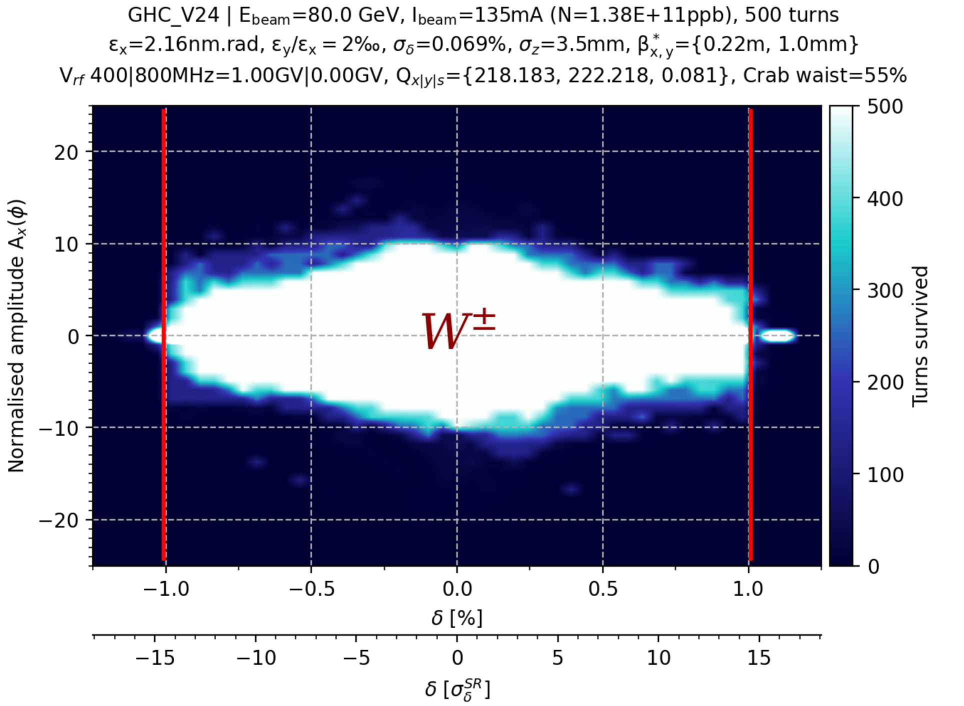
but the momentum compaction factor is larger α_{GHC}=7.5e-6 and α_{LCC}= 8.8e-6

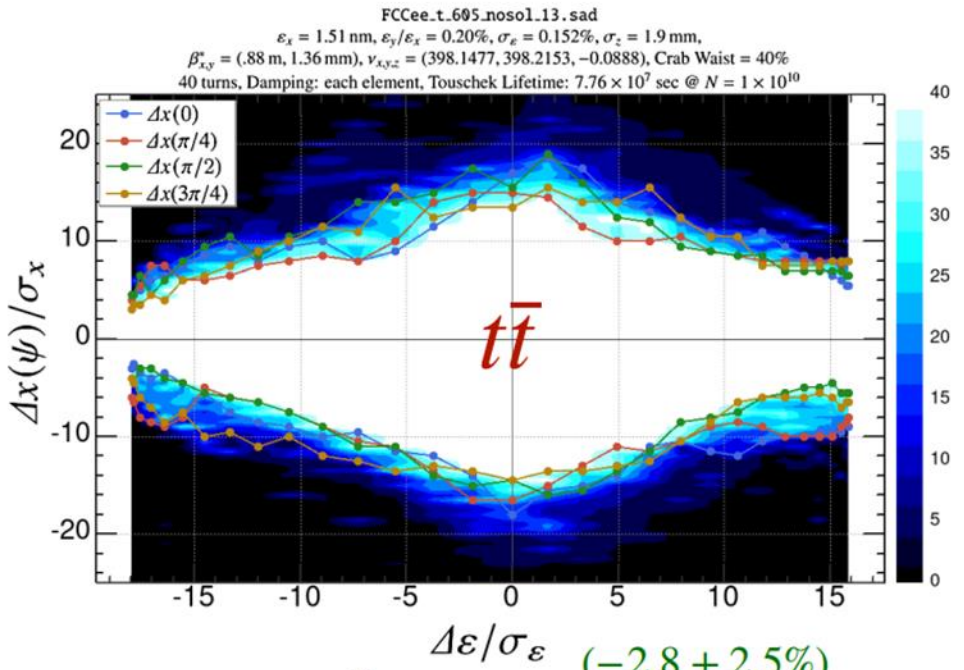
Is it important to get to Q_s=0.089 with the LCC lattice ?

MA comparison between SAD & Xsuite for the GHC lattice and against LCC lattice


FCCee_z_605_nosol_2.sad
ε_x = .7 nm, $\varepsilon_y/\varepsilon_x$ = 0.20%, σ_ε = 0.039%, σ_z = 5.6 mm,
$\beta^*_{x,y}$ = (.11 m, .7 mm), $\nu_{x,y,z}$ = (218.1585, 222.2003, −0.0289), Crab Waist = 70%
2400 turns, Damping: each element, Touschek Lifetime: 99357 sec @ $N = 1 \times 10^{10}$
$\Delta x(0)$
$\Delta x(\pi/4)$
$\Delta x(\pi/2)$
$\Delta x(3\pi/4)$
Z
$\Delta x(\psi)/\sigma_x$
$\Delta\varepsilon/\sigma_\varepsilon$ (±1.0%)
GHC_V24 | E_{beam}=45.6 GeV, I_{beam}=1282mA (N=2.16E+11ppb), 512 turns
ε_x=0.70nm.rad, $\varepsilon_y/\varepsilon_x$ = 2‰, σ_δ=0.039%, σ_z=5.5mm, $\beta^*_{x,y}$={0.10m, 0.7mm}
V_{rf} 400|800MHz=0.08GV|0.00GV, $Q_{x|y|s}$={218.156, 222.197, 0.029}, Crab waist=70%
Normalised amplitude $A_x(\phi)$
Z
Turns survived
δ [%]
δ [σ_δ^{SR}]
FCCee_h_605_nosol_2.sad
ε_x = .66 nm, $\varepsilon_y/\varepsilon_x$ = 0.20%, σ_ε = 0.102%, σ_z = 3.3 mm,
$\beta^*_{x,y}$ = (.24 m, 1 mm), $\nu_{x,y,z}$ = (398.1496, 398.2199, −0.0334), Crab Waist = 50%
130 turns, Damping: each element, Touschek Lifetime: 6.91×10^6 sec @ $N = 1 \times 10^{10}$
$\Delta x(0)$
$\Delta x(\pi/4)$
$\Delta x(\pi/2)$
$\Delta x(3\pi/4)$
Zh
$\Delta x(\psi)/\sigma_x$
$\Delta\varepsilon/\sigma_\varepsilon$ (±1.9%)
GHC_V24 | E_{beam}=120.0 GeV, I_{beam}=26mA (N=1.70E+11ppb), 150 turns
ε_x=0.66nm.rad, $\varepsilon_y/\varepsilon_x$ = 2‰, σ_δ=0.104%, σ_z=3.2mm, $\beta^*_{x,y}$={0.24m, 1.0mm}
V_{rf} 400|800MHz=2.09GV|0.00GV, $Q_{x|y|s}$={398.138, 398.208, 0.033}, Crab waist=50%
$\phi = 0$
$\phi = \pi/4$
$\phi = \pi/2$
$\phi = 3\pi/4$
Zh
Normalised amplitude $A_x(\phi)$
Turns survived
δ [%]
δ [σ_δ^{SR}]


FCCee_w_605_nosol_9.sad
ε_x = 2.16 nm, $\varepsilon_y/\varepsilon_x$ = 0.20%, σ_ε = 0.069%, σ_z = 3.5 mm,
$\beta^*_{x,y}$ = (.22 m, 1 mm), $\nu_{x,y,z}$ = (218.1854, 222.2203, −0.0809), Crab Waist = 55%
440 turns, Damping: each element, Touschek Lifetime: 3.91×10^6 sec @ $N = 1 \times 10^{10}$
$\Delta x(0)$
$\Delta x(\pi/4)$
$\Delta x(\pi/2)$
$\Delta x(3\pi/4)$
$W^\pm$
$\Delta x(\psi)/\sigma_x$
$\Delta\varepsilon/\sigma_\varepsilon$ (±1.0%)


GHC_V24 | E_{beam}=80.0 GeV, I_{beam}=135mA (N=1.38E+11ppb), 500 turns
ε_x=2.16nm.rad, $\varepsilon_y/\varepsilon_x$ = 2‰, σ_δ=0.069%, σ_z=3.5mm, $\beta^*_{x,y}$={0.22m, 1.0mm}
V_{rf} 400|800MHz=1.00GV|0.00GV, $Q_{x|y|s}$={218.183, 222.218, 0.081}, Crab waist=55%
$W^\pm$
Normalised amplitude $A_x(\phi)$
Turns survived
δ [%]
δ [σ_δ^{SR}]


FCCee_t_605_nosol_13.sad
ε_x = 1.51 nm, $\varepsilon_y/\varepsilon_x$ = 0.20%, σ_ε = 0.152%, σ_z = 1.9 mm,
$\beta^*_{x,y}$ = (.88 m, 1.36 mm), $\nu_{x,y,z}$ = (398.1477, 398.2153, −0.0888), Crab Waist = 40%
40 turns, Damping: each element, Touschek Lifetime: 7.76×10^7 sec @ $N = 1 \times 10^{10}$
$\Delta x(0)$
$\Delta x(\pi/4)$
$\Delta x(\pi/2)$
$\Delta x(3\pi/4)$
$t\bar{t}$
$\Delta x(\psi)/\sigma_x$
$\Delta\varepsilon/\sigma_\varepsilon$ (−2.8 + 2.5%)

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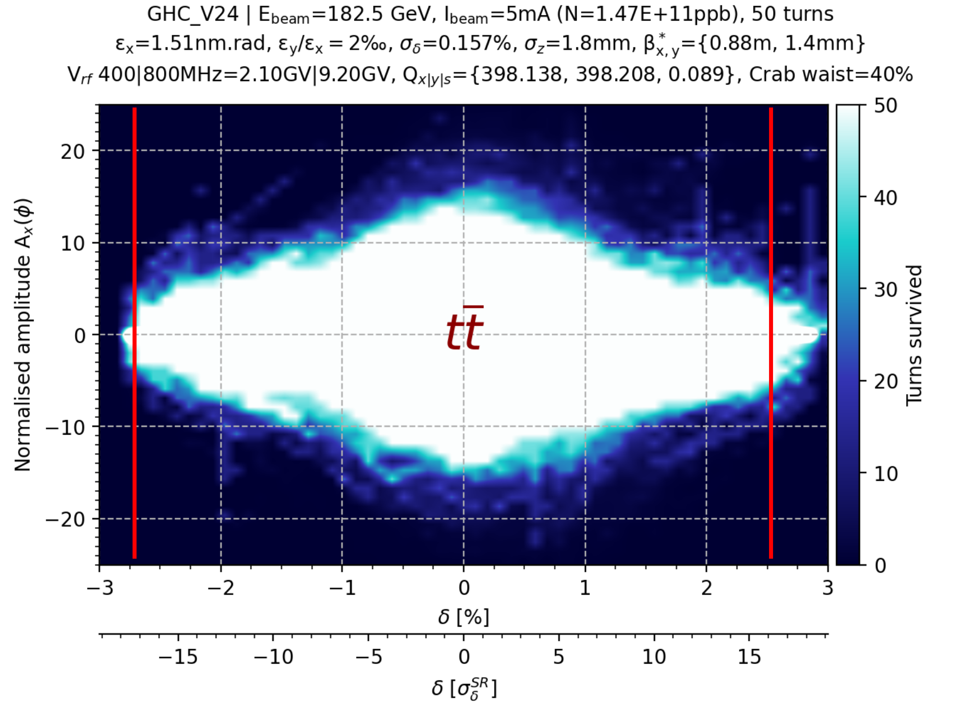
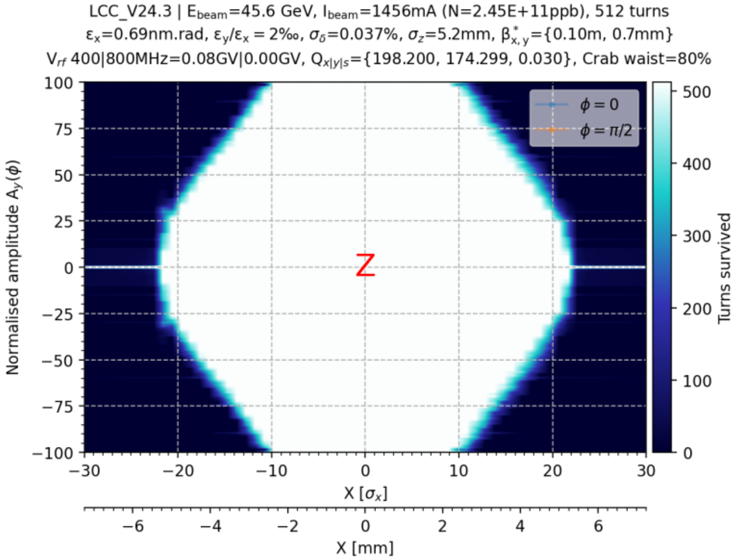
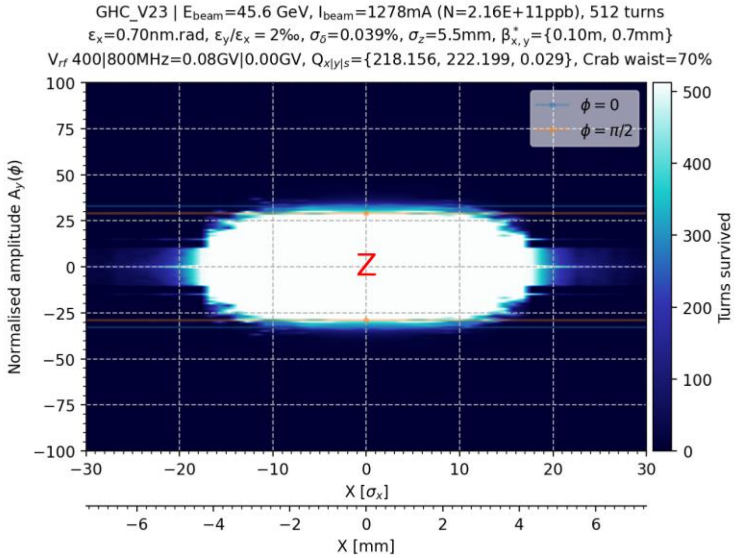
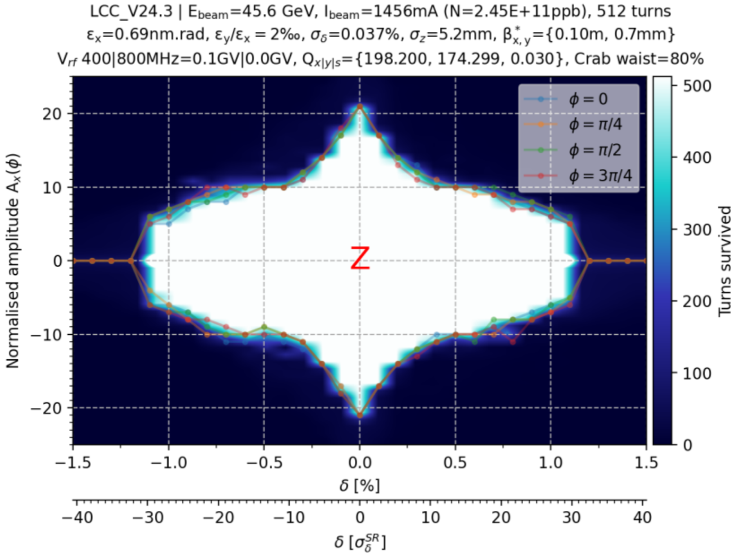

GHC_V24 | E_{beam}=182.5 GeV, I_{beam}=5mA (N=1.47E+11ppb), 50 turns
ε_x=1.51nm.rad, $\varepsilon_y/\varepsilon_x$ = 2‰, σ_δ=0.157%, σ_z=1.8mm, $\beta^*_{x,y}$={0.88m, 1.4mm}
V_{rf} 400|800MHz=2.10GV|9.20GV, $Q_{x|y|s}$={398.138, 398.208, 0.089}, Crab waist=40%
$t\bar{t}$
Normalised amplitude $A_x(\phi)$
Turns survived
δ [%]
δ [σ_δ^{SR}]

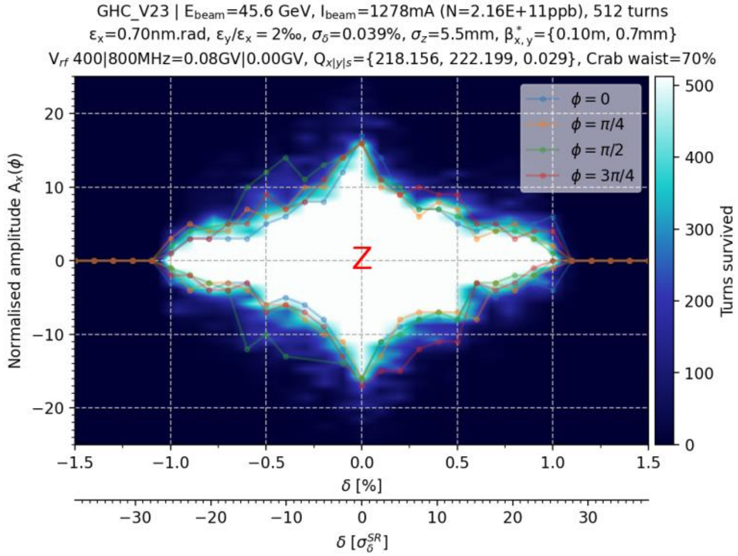
Comparison GHC vs. LCC @ Z energy

Nominal magnet strengths (v92a)



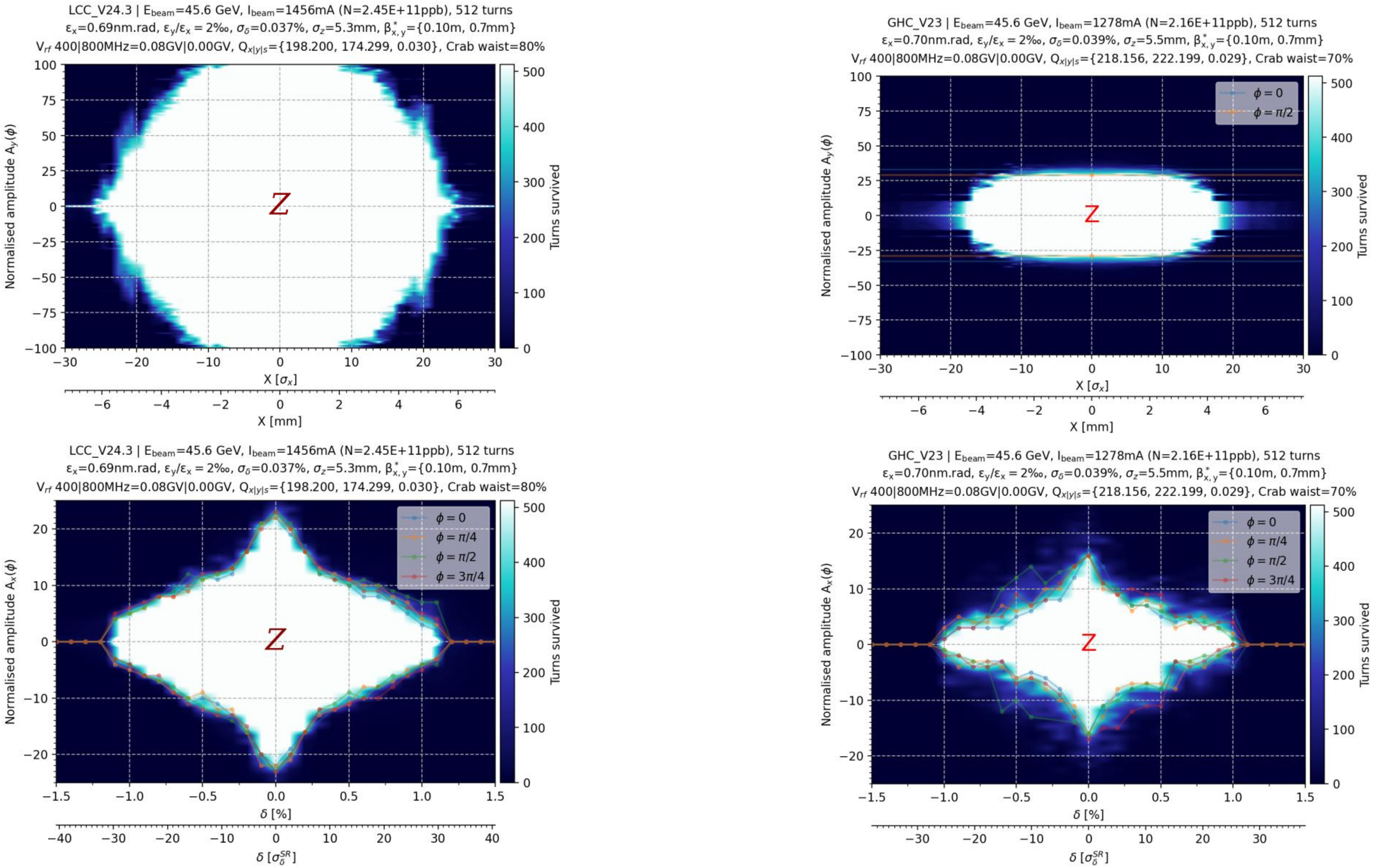






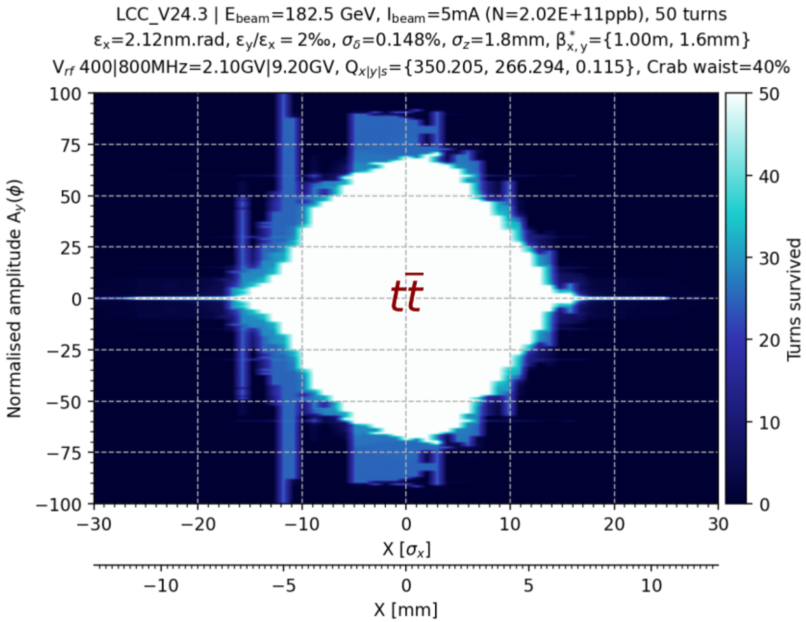
Comparison GHC vs. LCC (opti) @ Z energy

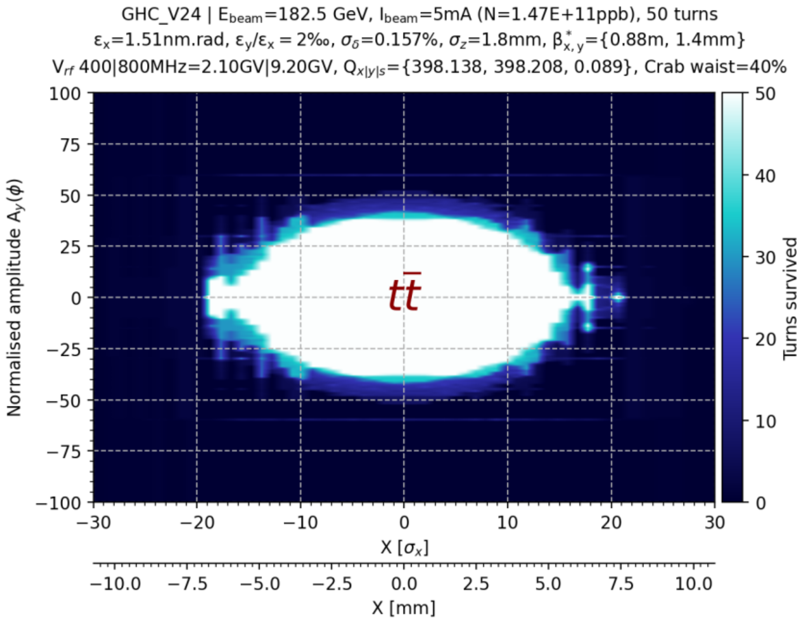
Optimized magnet strengths (v92a)



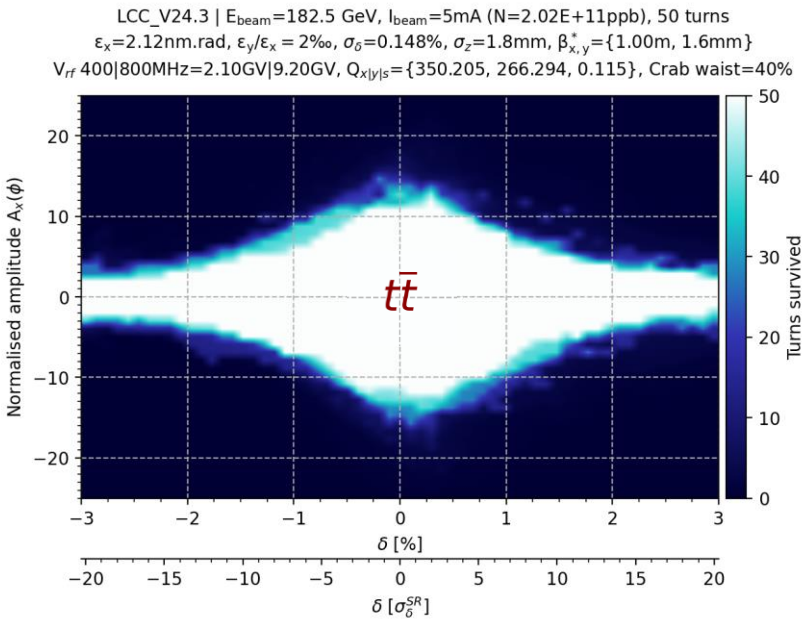
Comparison GHC vs. LCC @ tt̄ energy

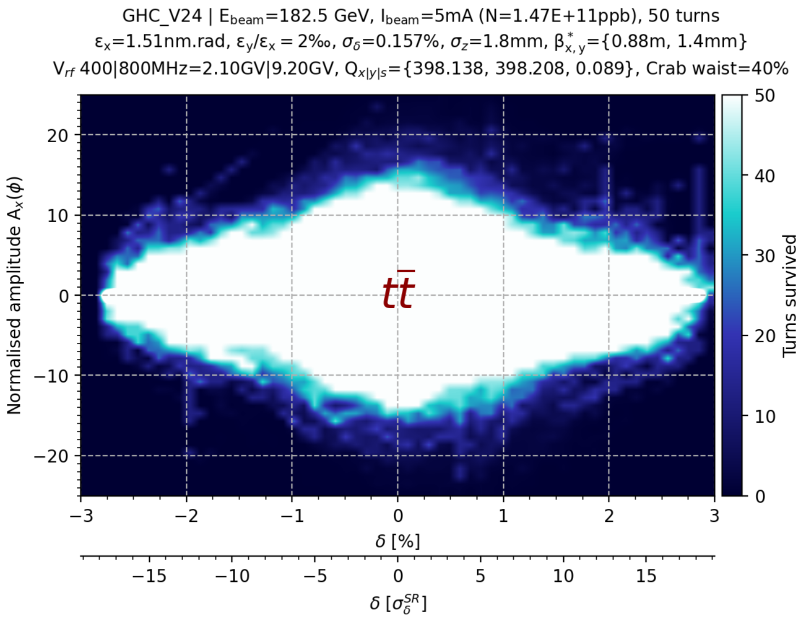
DA





MA

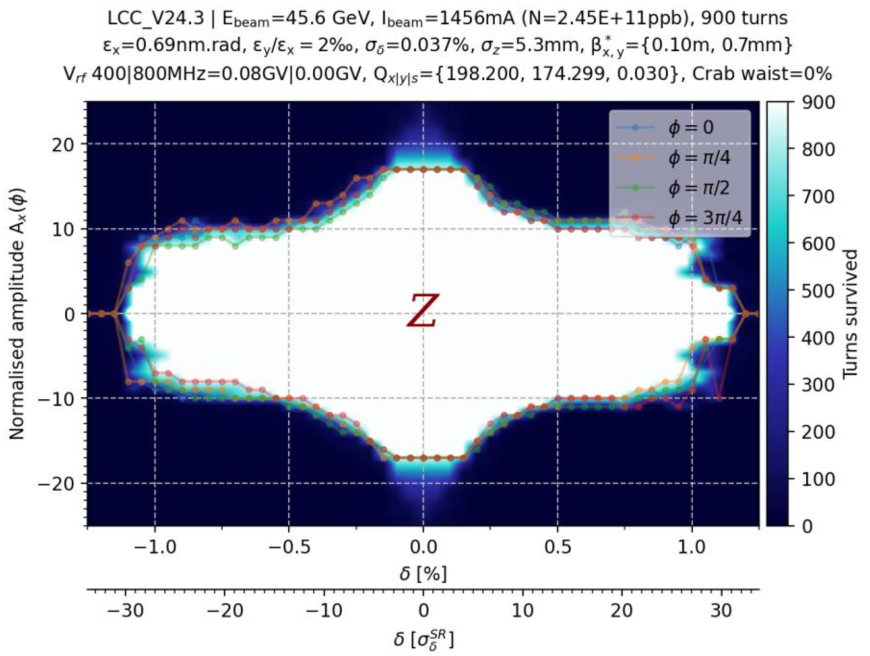


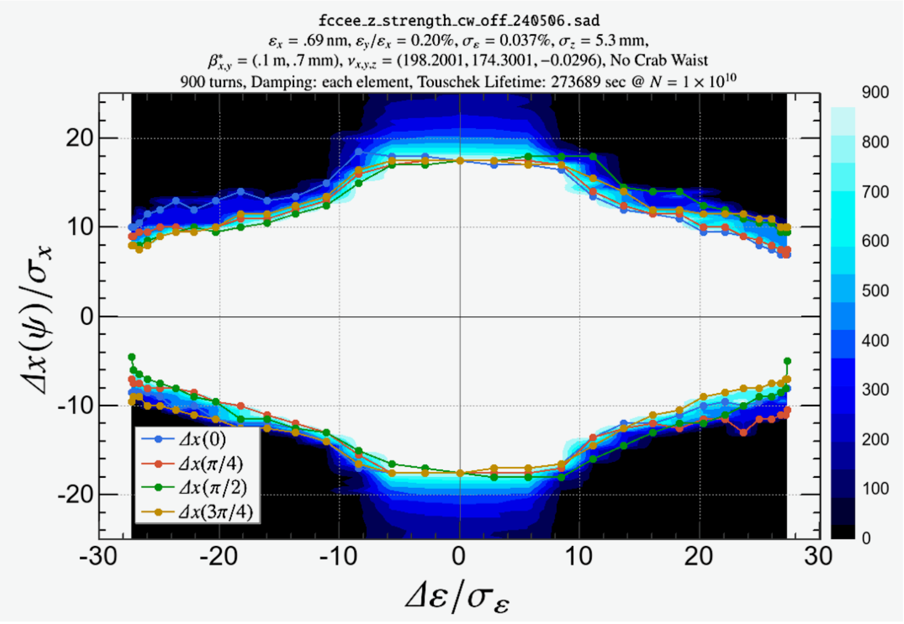


MA comparison between SAD and Xsuite for the LCC lattice

Differences between Xsuite and SAD (CW=0%)

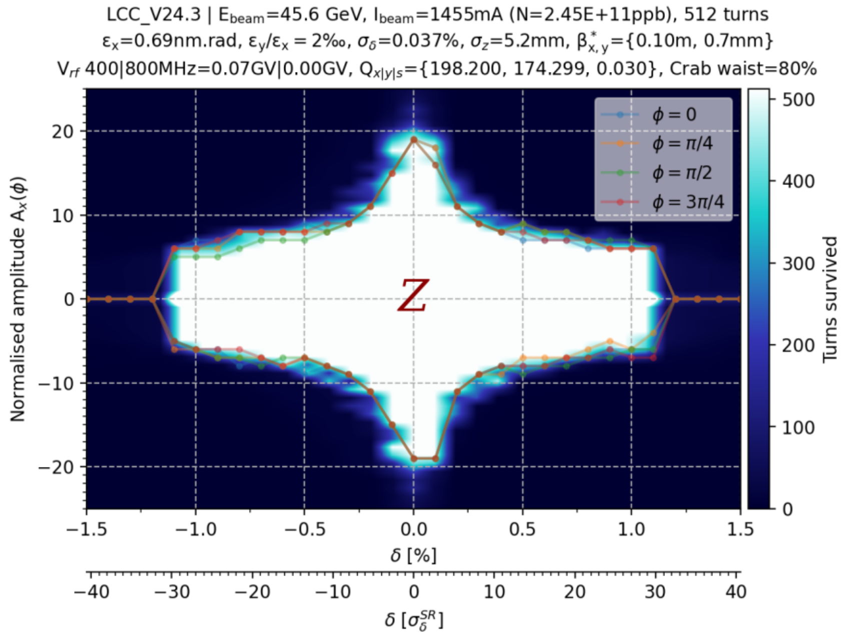
- I spotted differences (in the converted MADX file, Oide-san sent me) in which the variable cs_comp is not used and the decapoles not defined.
- It could explain the differences observed **with** and **without** crab waist as the decapoles are turned on also **without** crab waist.

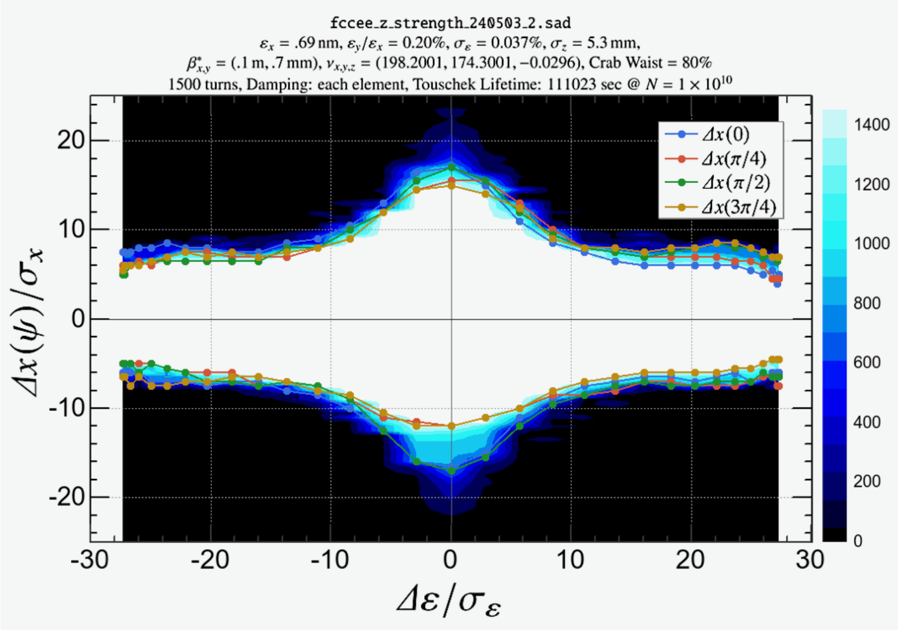




Differences between Xsuite and SAD (CW=80%)

- I spotted differences (in the converted MADX file, Oide-san sent me) in which the variable cs_comp is not used and the decapoles not defined.
- It could explain the differences observed **with** and **without** crab waist as the decapoles are turned on also **without** crab waist.



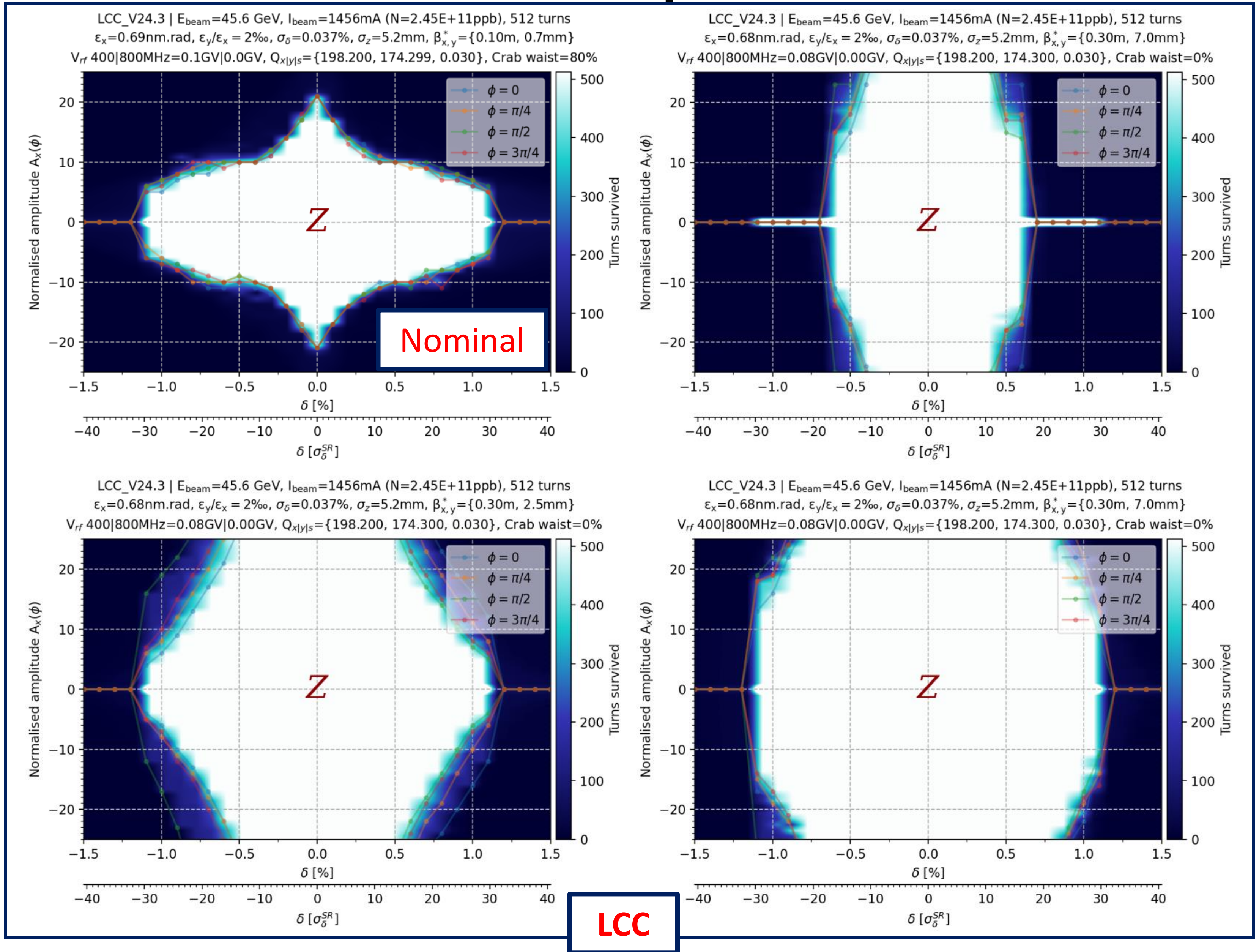


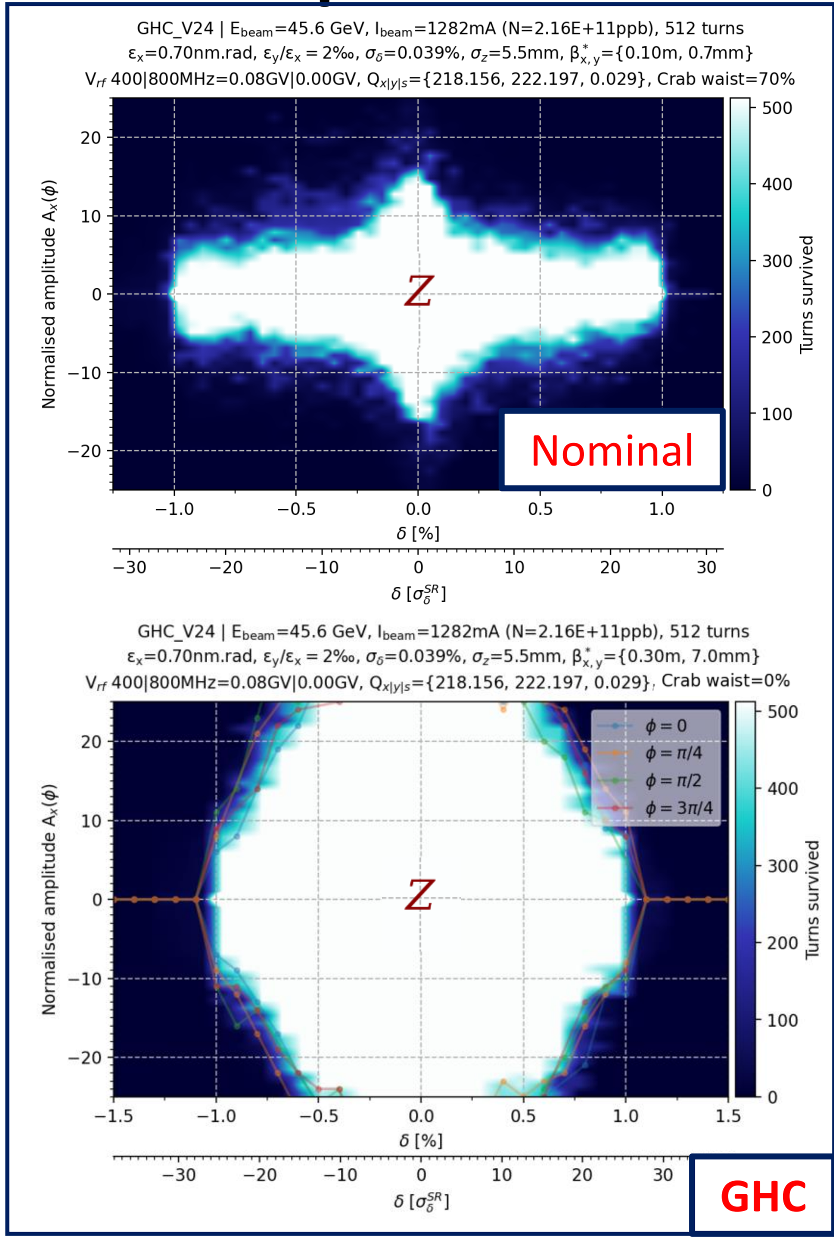
MA study comparison between relaxed vs. nominal optics

-- GHC lattice detuned to β^*_x= 0.33m & β^*_y=7 mm

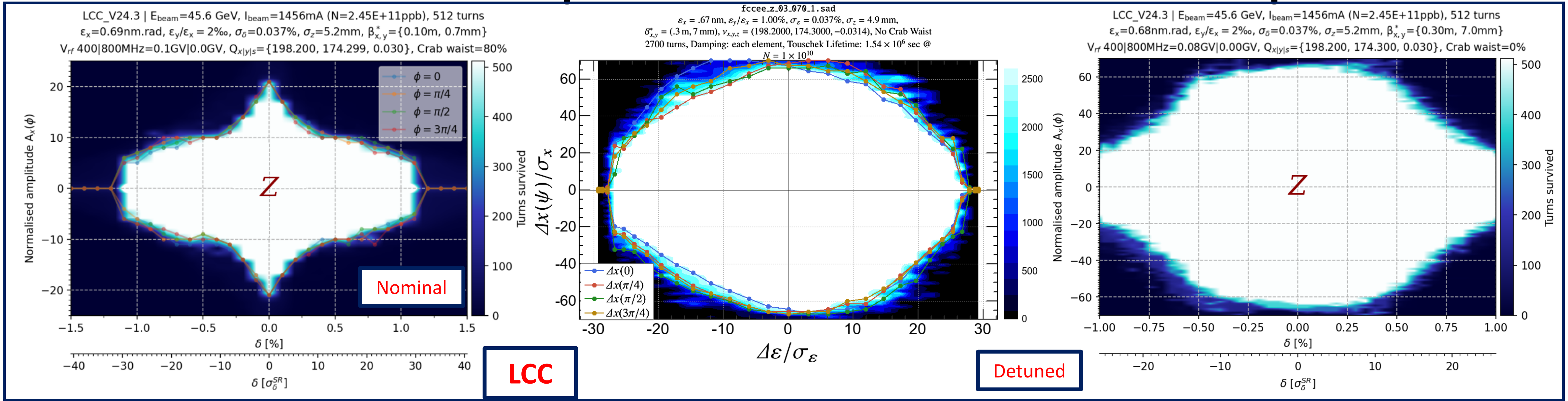
-- LCC lattice detuned to β^*_x= 0.30m & β^*_y=7 mm

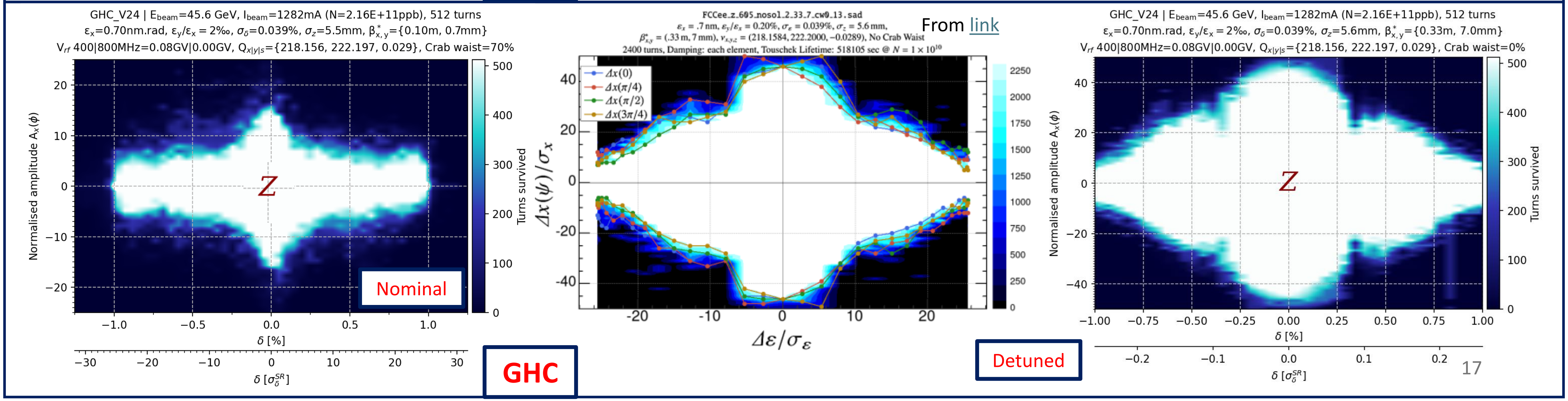
Momentum Acceptance of the relaxed optics





Momentum Acceptance of the relaxed optics





Summary and outlook

- **One RF section**: Decreasing by about 5% the total RF voltage of LCC at tt energy still result in ±3% MA and Q_s=0.107. 10% is too much though.
- **Xsuite/SAD MA comparison**: The MA results for the GHC lattice agree well with CW. The MA results for the LCC lattice agree well without CW.
- **Detuned optics**: The MA of the GHC detuned optics goes beyond $40\sigma_x$ on-energy and $10\sigma_x$ at ±1%, whereas LCC detuned optics goes beyond $60\sigma_x$ on-energy and $20\sigma_x$ at ±1%.

Outlook:

- Implement the DA/MA with Xsuite as a test in the Gitlab lattice repository, along with SAD?

- Compare Xsuite/SAD MA results for the LCC lattice including decapoles (and cs_comp with CW).

- Implement the optimum magnet strengths for the LCC lattice at ttbar energy.